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Deen et al.

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(54) **LATERAL SPIN VALVE READER WITH LARGE-AREA TUNNELING SPIN-INJECTOR**

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(21) Appl. No.: **15/183,347**

(22) Filed: **Jun. 15, 2016**

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G11B 5/39 (2006.01)

(52) **U.S. Cl.**
CPC ***G11B 5/398*** (2013.01); ***G11B 5/397*** (2013.01); ***G11B 5/3909*** (2013.01); ***G11B 5/3912*** (2013.01); ***G11B 5/3948*** (2013.01); *G11B 2005/3996* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,020,013	B2	3/2006	Johnson
7,193,891	B2	3/2007	Johnson
7,209,328	B2	4/2007	Ito et al.
7,280,322	B2	10/2007	Takahashi et al.
7,298,597	B2	11/2007	Carey et al.
7,522,392	B2	4/2009	Carey et al.
8,072,713	B2	12/2011	Yamada et al.
8,717,715	B1	5/2014	Sato et al.
9,042,061	B2	5/2015	Dimitrov et al.
9,064,509	B2	6/2015	Dimitrov et al.
2006/0022220	A1	2/2006	Inomata et al.
2007/0253116	A1	11/2007	Takahashi
2007/0253121	A1	11/2007	Yamada et al.
2009/0154030	A1	6/2009	Yamada et al.
2010/0119875	A1	5/2010	Sasaki
2010/0296202	A1	11/2010	Boone, Jr. et al.
2011/0042648	A1	2/2011	Koo et al.
2015/0029609	A1	1/2015	Kamiguchi et al.

(Continued)

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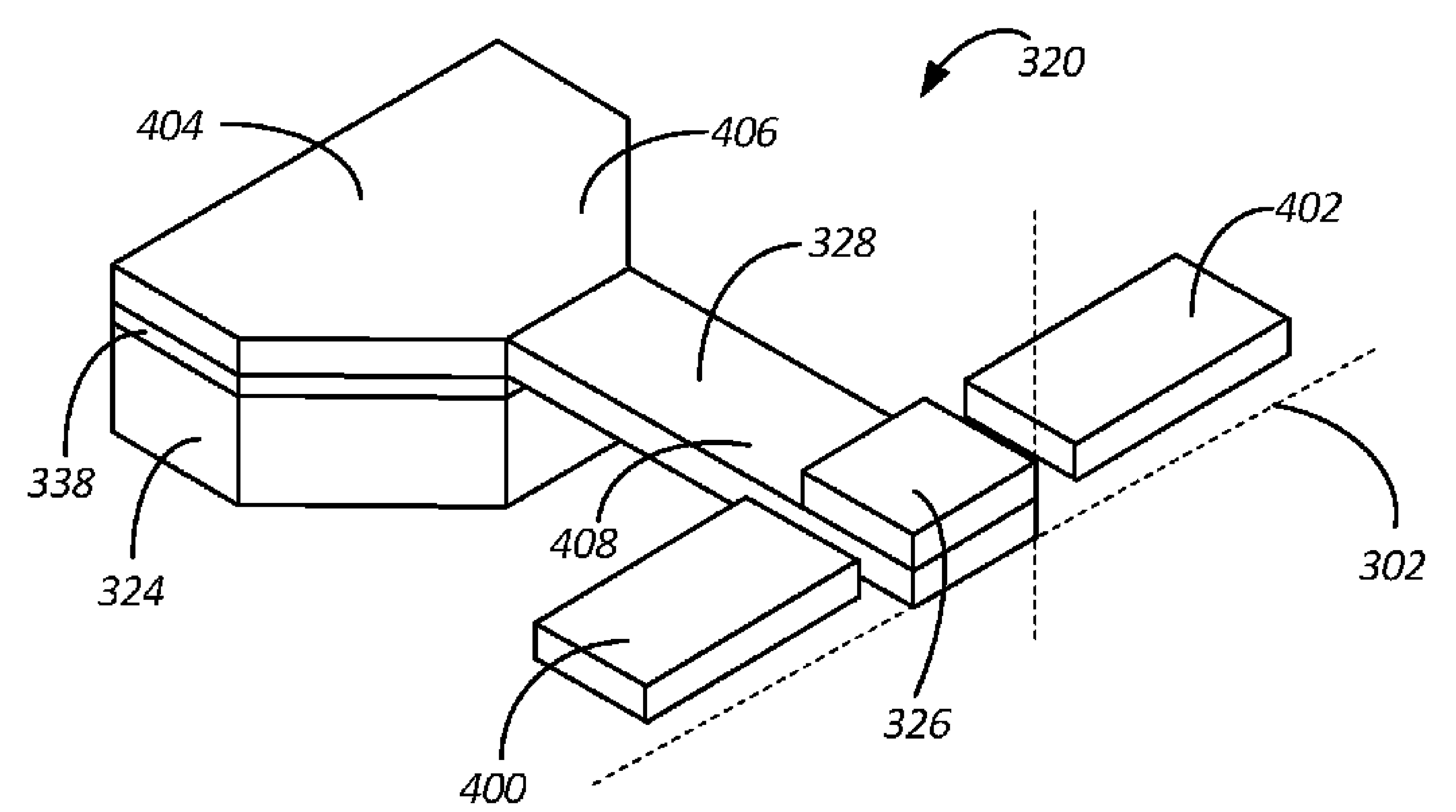
(57) **ABSTRACT**

A lateral spin valve reader includes a channel layer having a first end that is proximate to a bearing surface and a second end that is away from the bearing surface. The lateral spin valve reader also includes a detector structure disposed over an upper surface of a first portion of the channel layer that is proximate to the first end of the channel layer. A spin injection structure disposed below a lower surface of a second portion of the channel layer is proximate to the second end of the channel layer. An area of overlap between the spin injection structure and the second portion of the channel layer is substantially larger than an area of overlap between the detector structure and the first portion of the channel layer.

20 Claims, 10 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2015/0035524	A1*	2/2015	Sasaki et al.	G01R 33/093 324/244
2016/0154071	A1*	6/2016	Sasaki	G01R 33/093 360/313

* cited by examiner

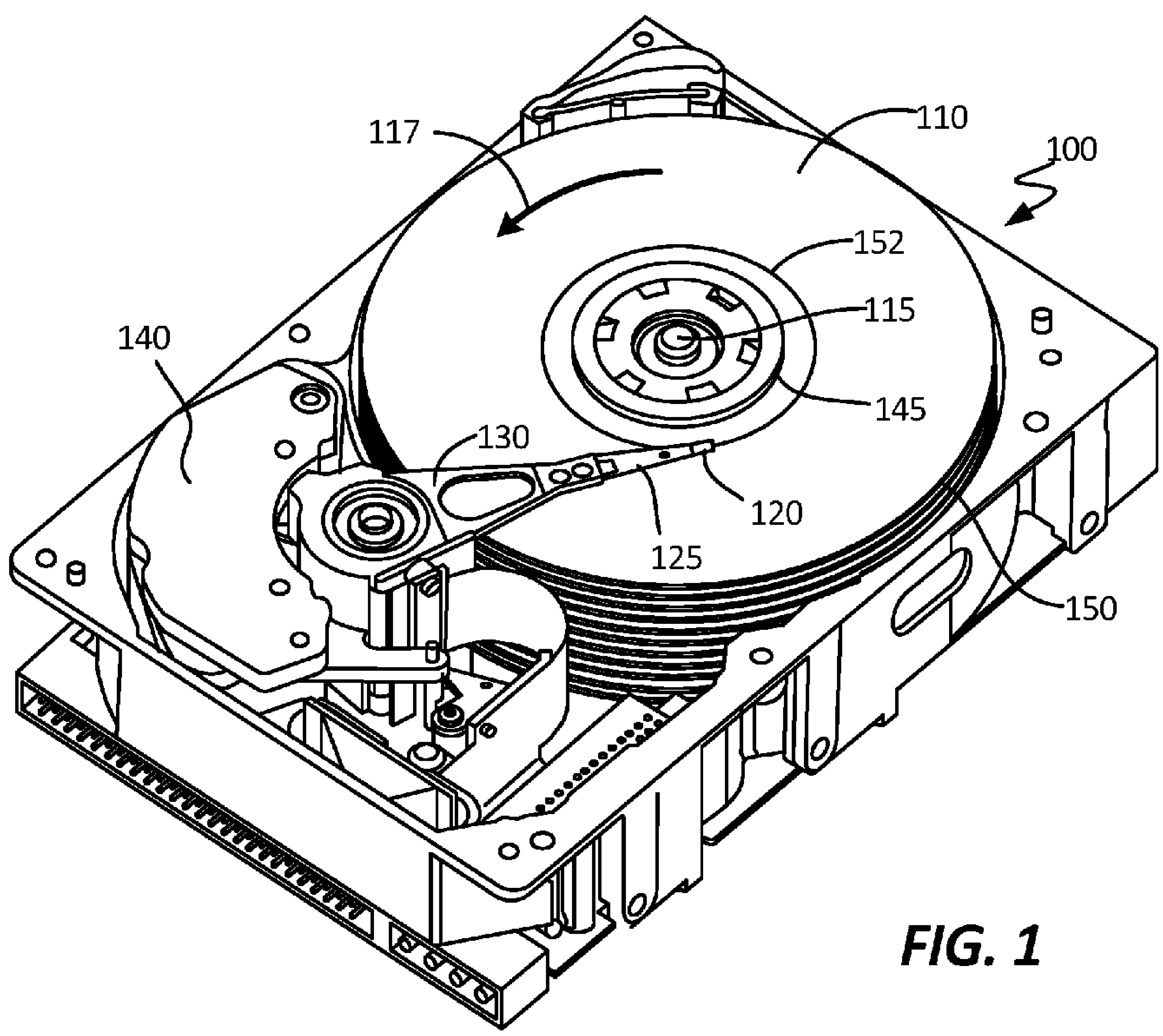


FIG. 1

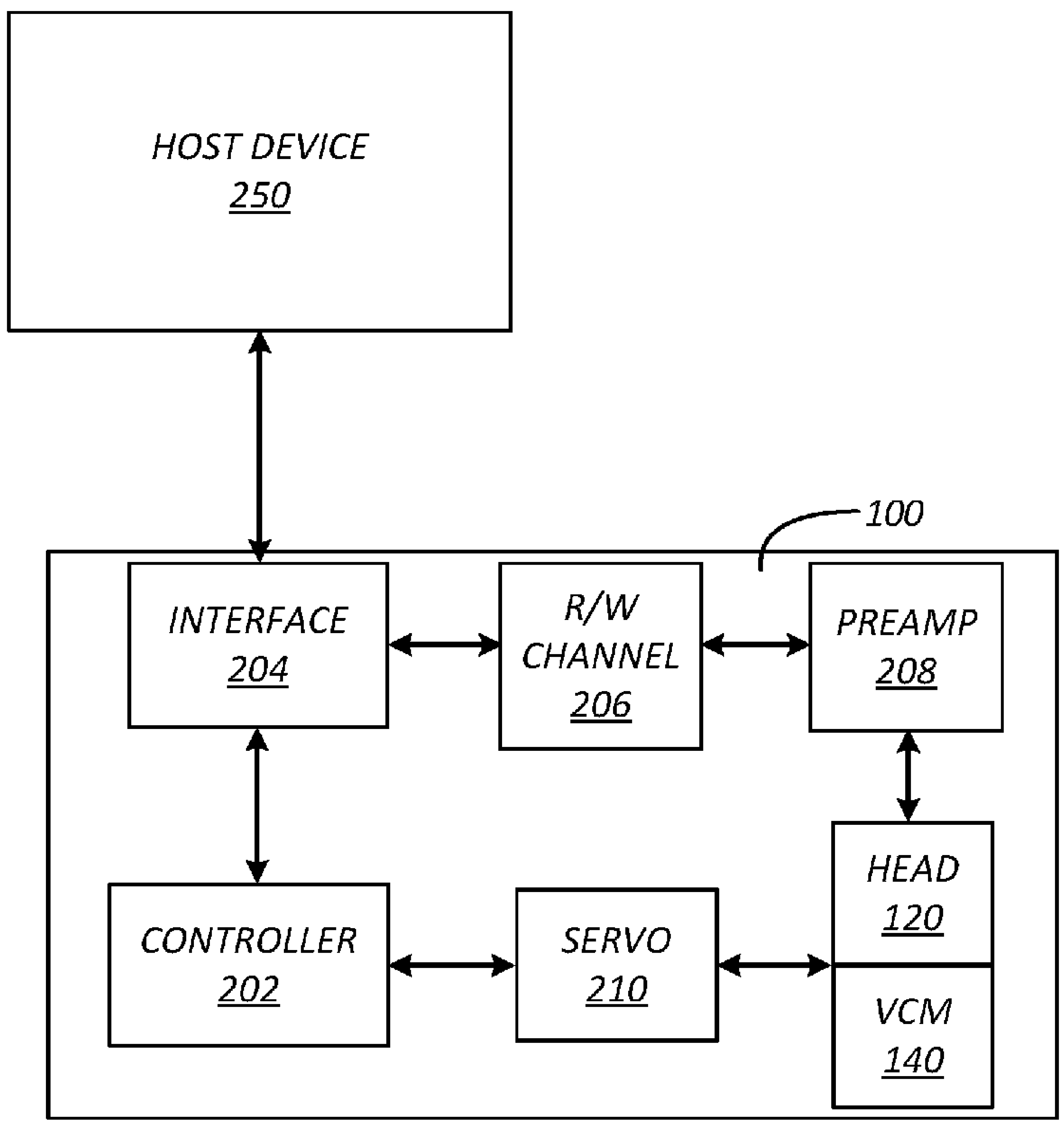
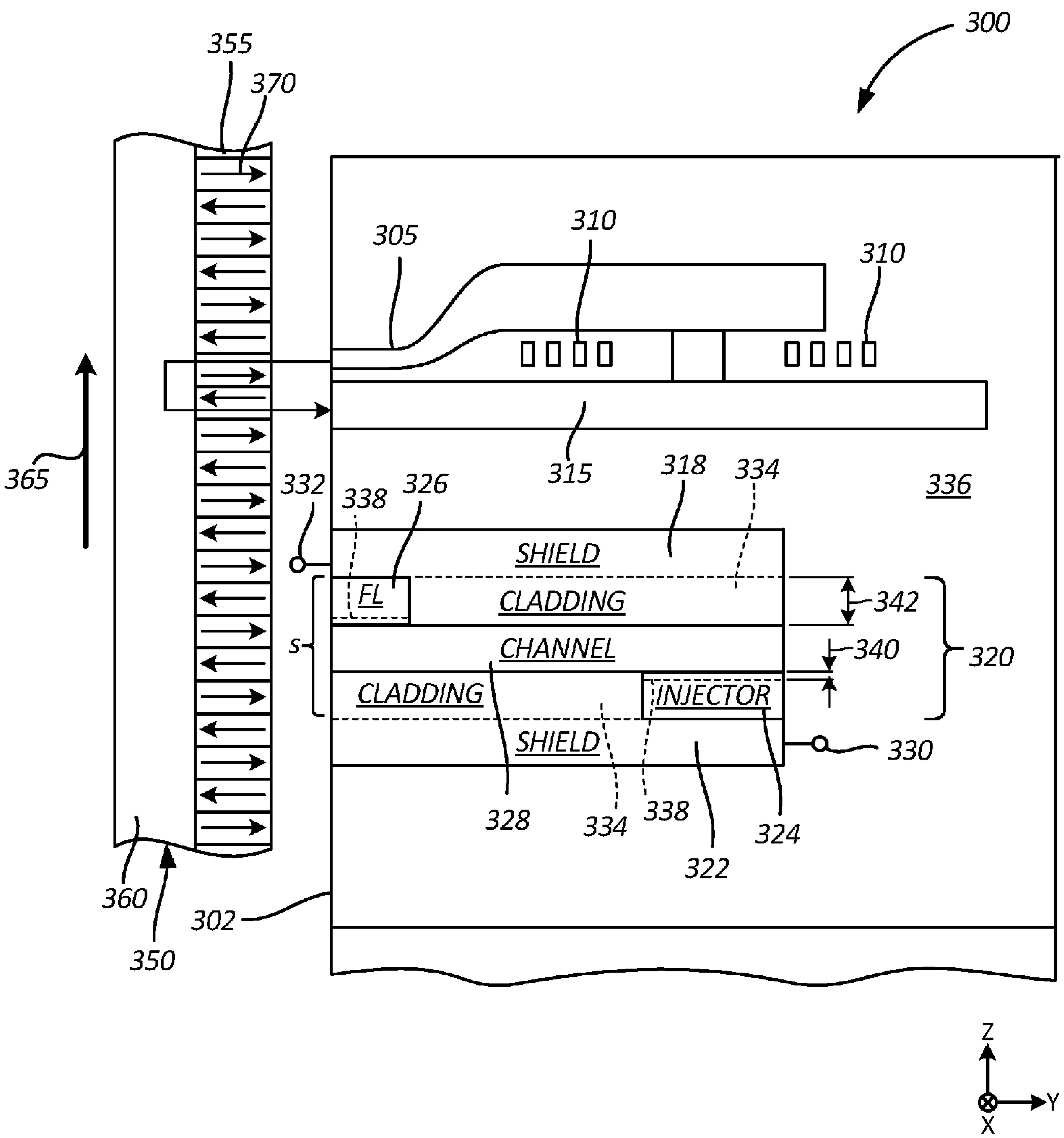

HOST DEVICE
250
100
INTERFACE
204
R/W
CHANNEL
206
PREAMP
208
HEAD
120
CONTROLLER
202
SERVO
210
VCM
140

FIG. 2



300
355
370
305
310
310
315
318
334
336
332
338
326
SHIELD
FL
CLADDING
342
365
s
CHANNEL
340
320
CLADDING
INJECTOR
SHIELD
330
328
334
338
324
322
360
302
350
Z
Y
X

FIG. 3A

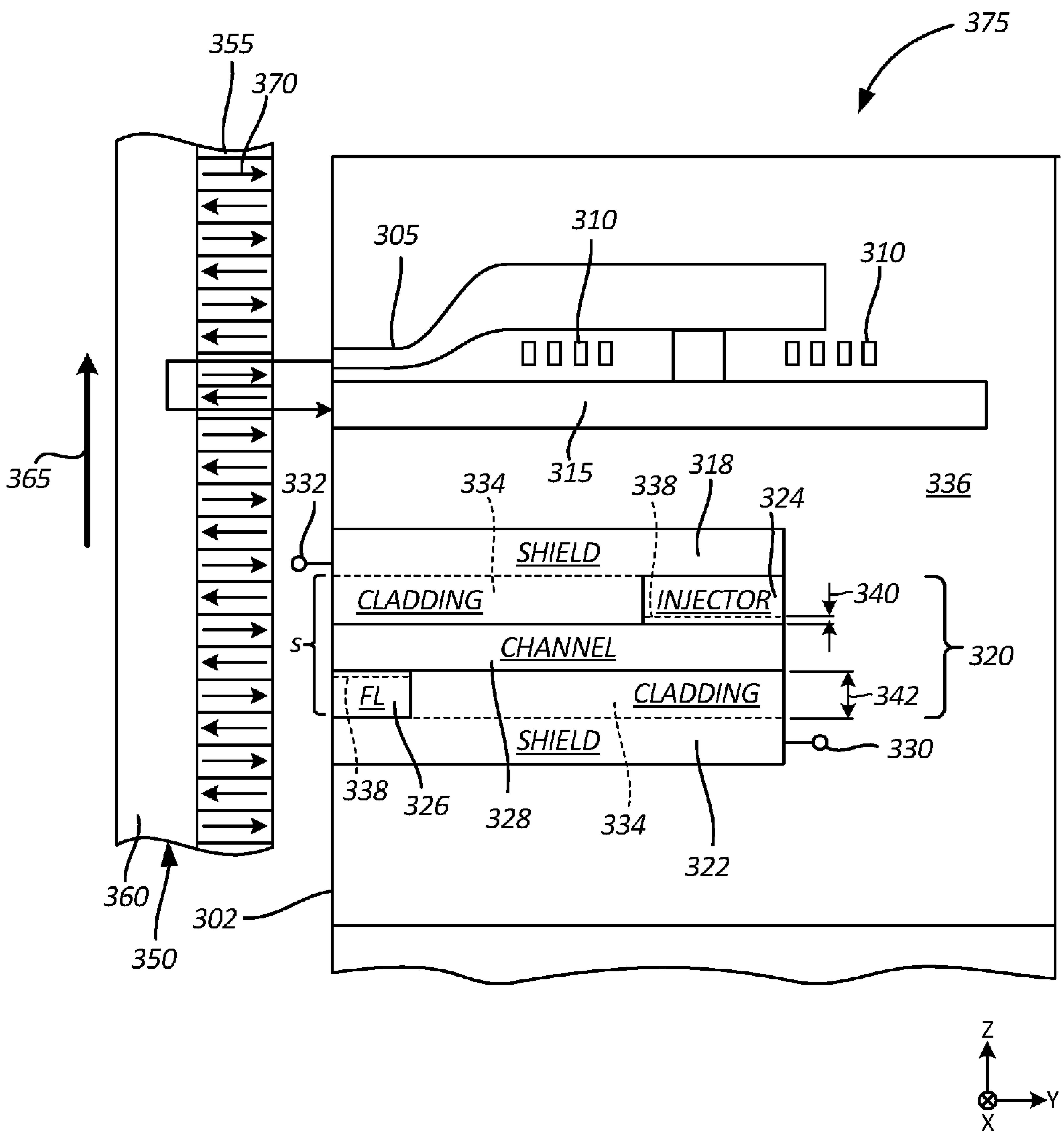
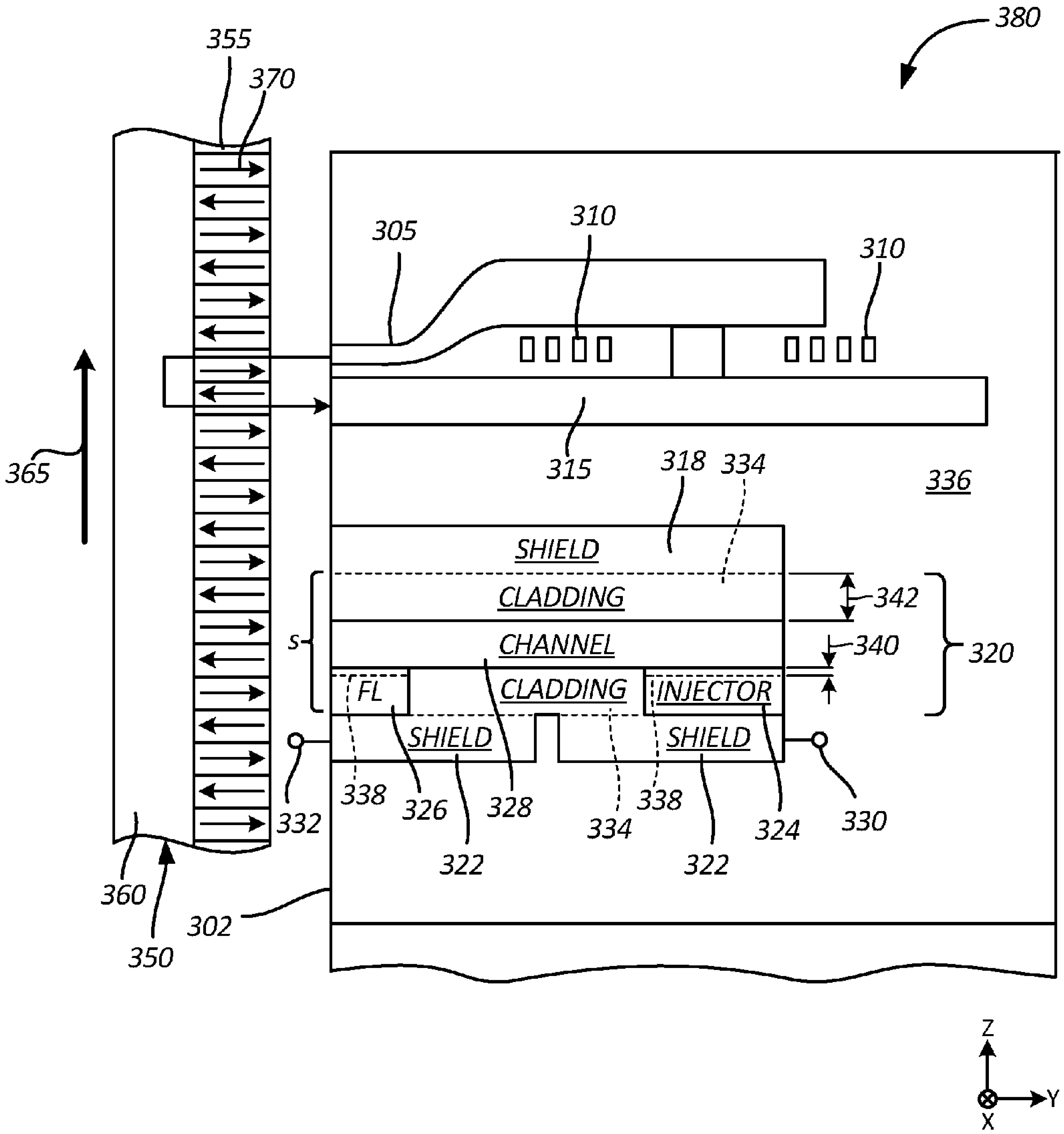

375
355
370
305
310
310
365
315
332
334
338
318
324
336
SHIELD
CLADDING
INJECTOR
340
s
CHANNEL
320
FL
CLADDING
342
SHIELD
330
338
326
328
334
322
360
302
350
Z
Y
X

FIG. 3B



380
355
370
305
310
310
365
315
318
334
336
SHIELD
CLADDING
342
s
CHANNEL
340
320
FL
CLADDING
INJECTOR
SHIELD
SHIELD
332
338
326
328
334
338
324
330
322
322
360
350
302
Z
Y
X

FIG. 3C

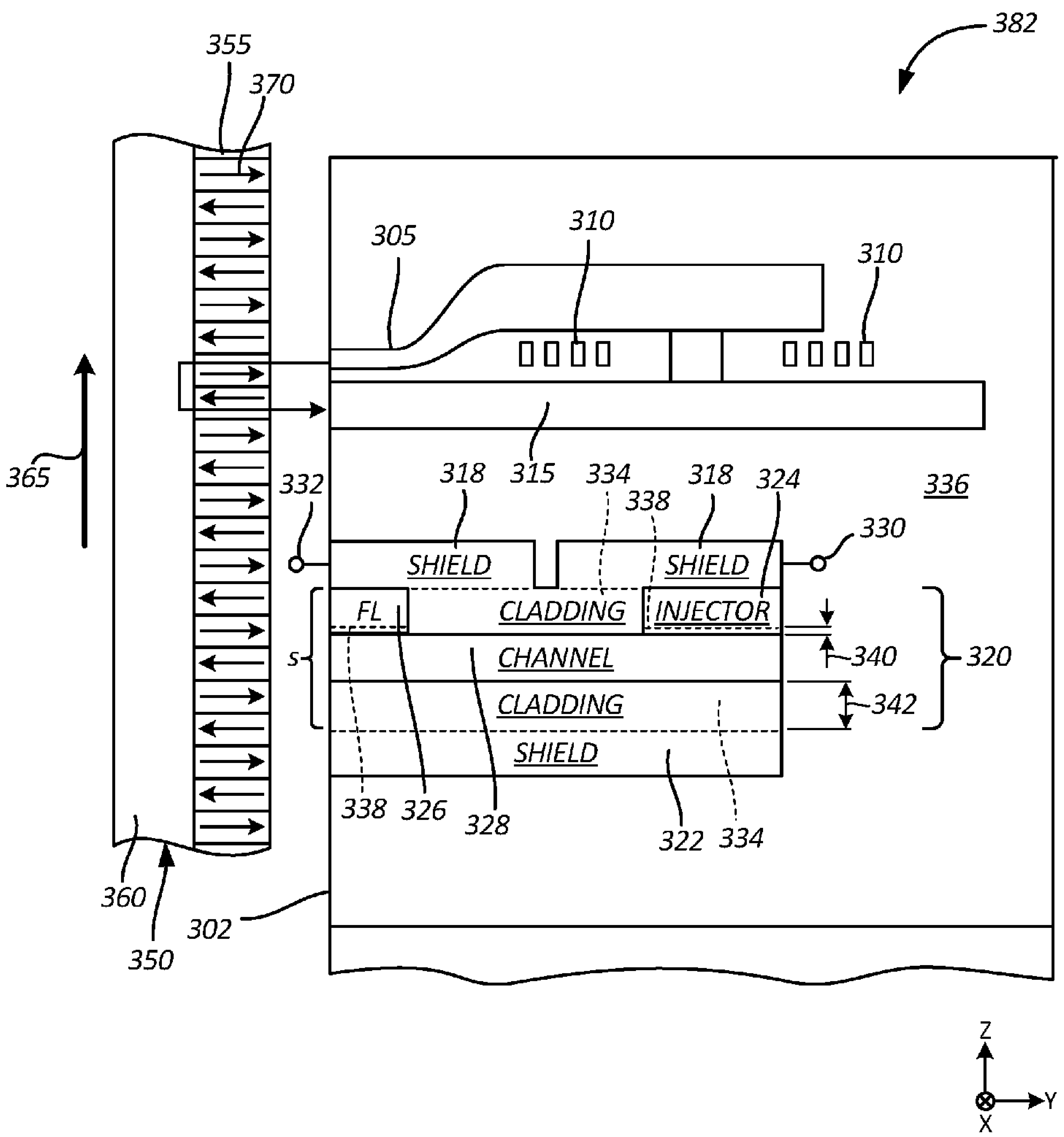

382
355
370
305
310
310
365
332
318
315
334
338
318
324
336
330
SHIELD
SHIELD
FL
CLADDING
INJECTOR
S
CHANNEL
340
320
CLADDING
342
SHIELD
338
326
328
322
334
360
302
350
Z
Y
X

FIG. 3D

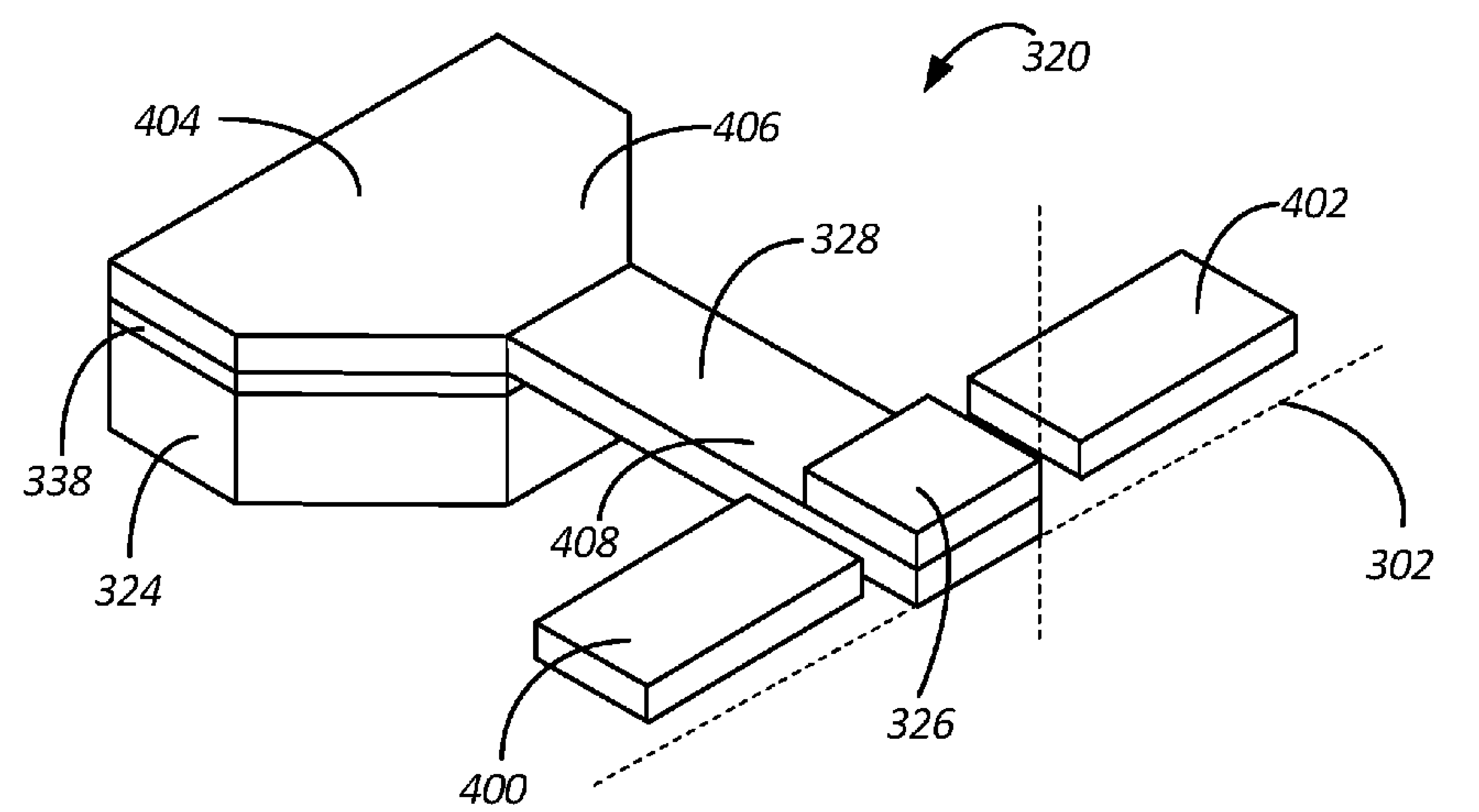

320
404
406
402
328
338
408
302
324
326
400

FIG. 4A

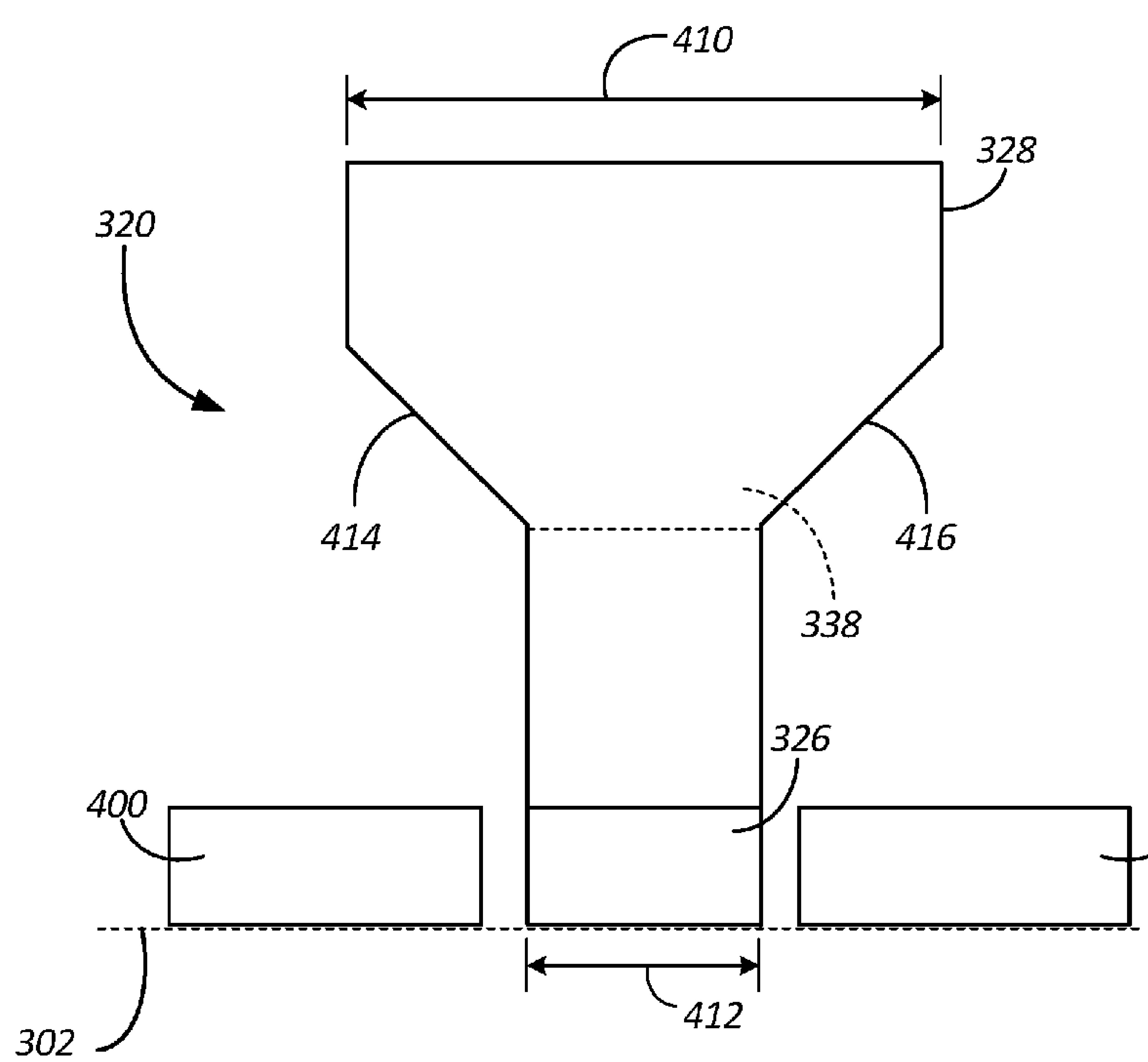

410
328
320
414
416
338
326
400
402
302
412

FIG. 4B

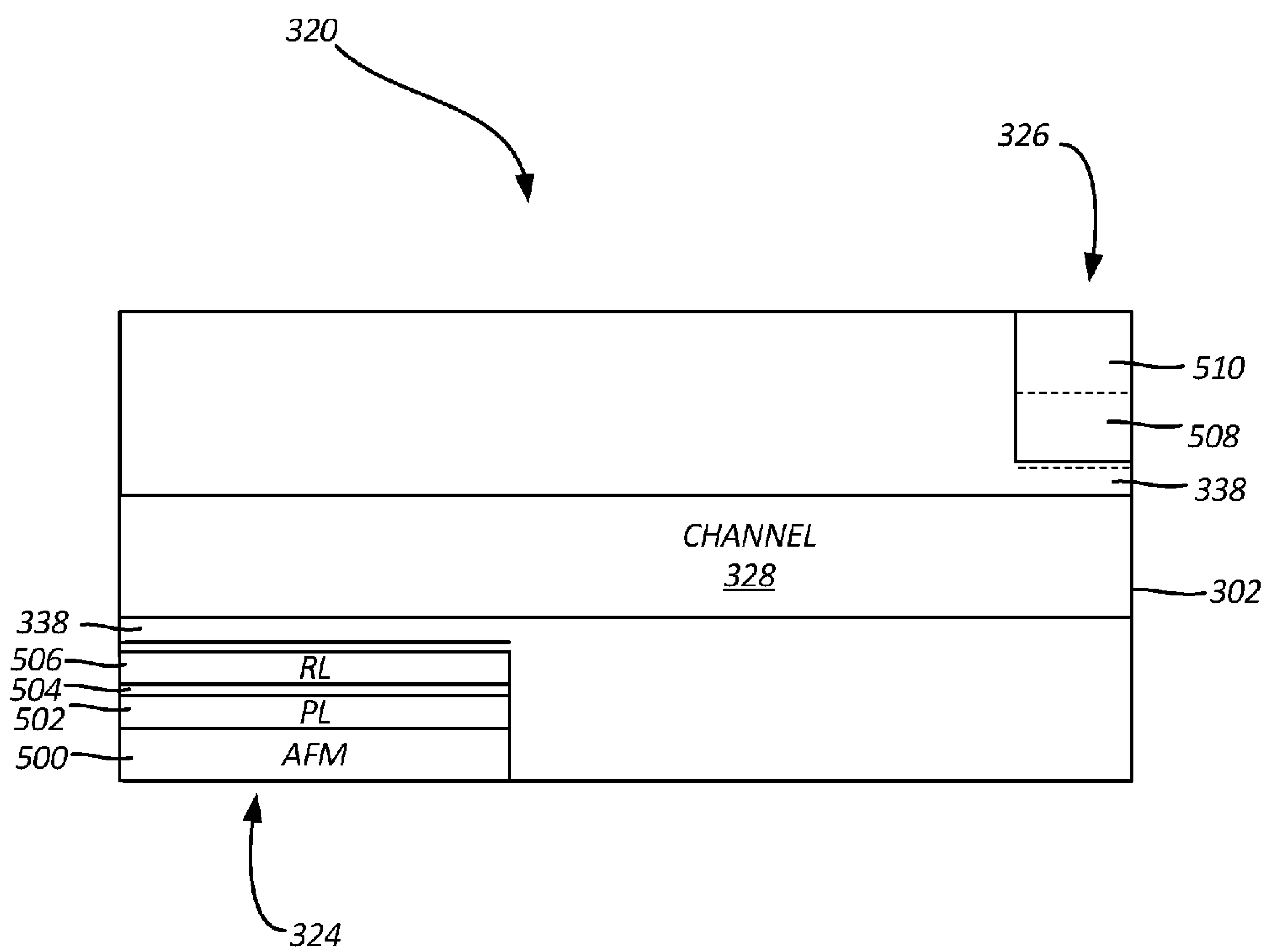

320
326
510
508
338
CHANNEL
328
302
338
506
504
502
500
RL
PL
AFM
324

FIG. 5

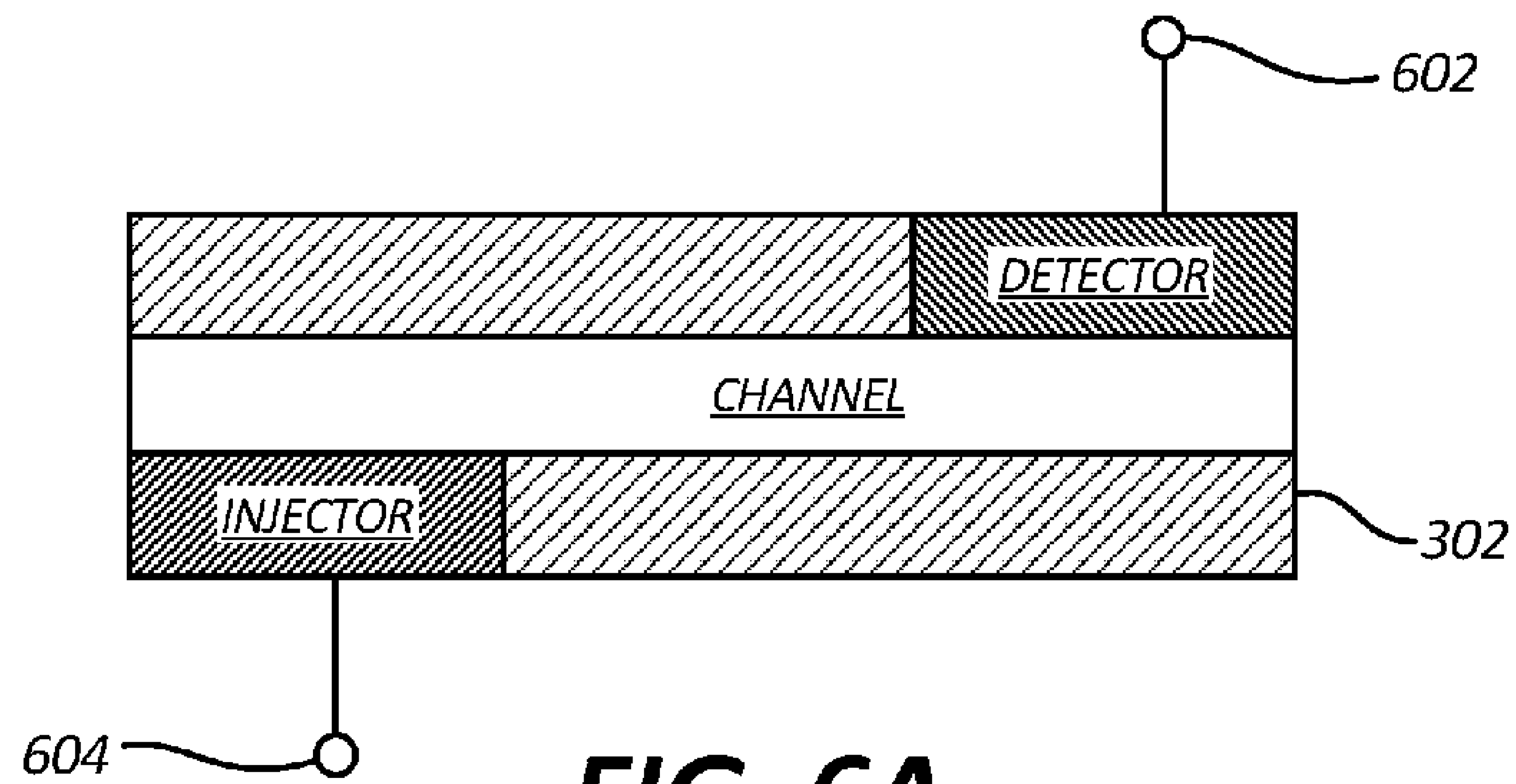


FIG. 6A

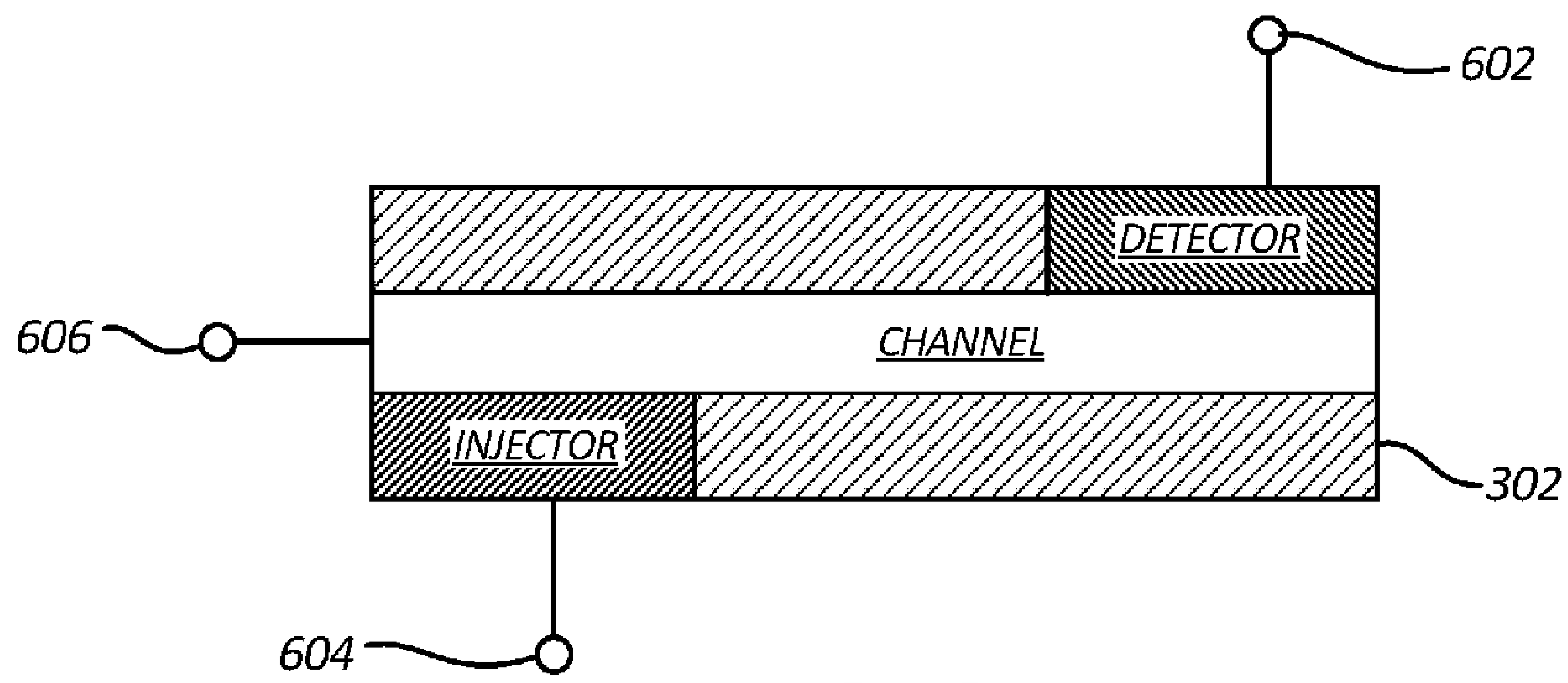


FIG. 6B

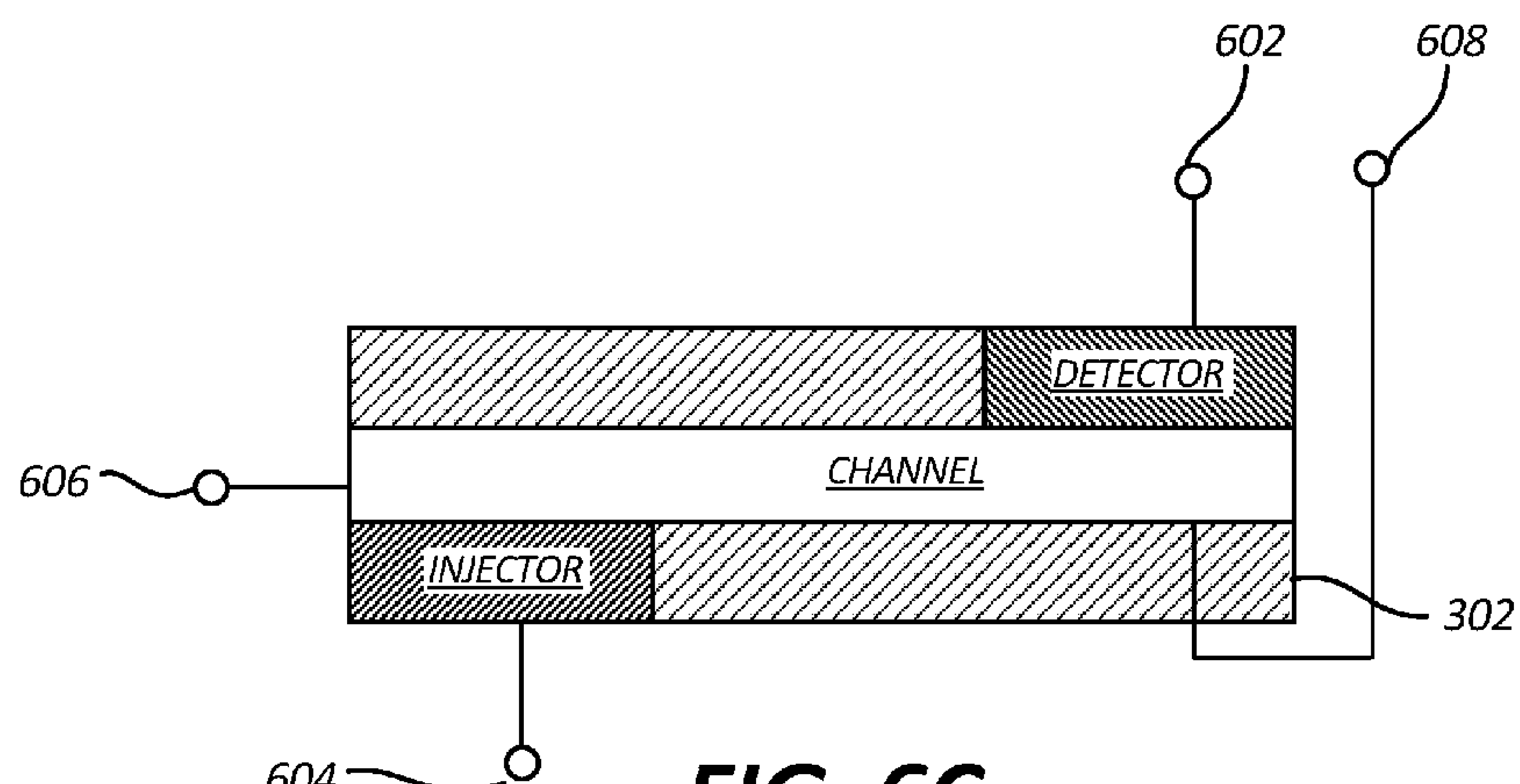


FIG. 6C

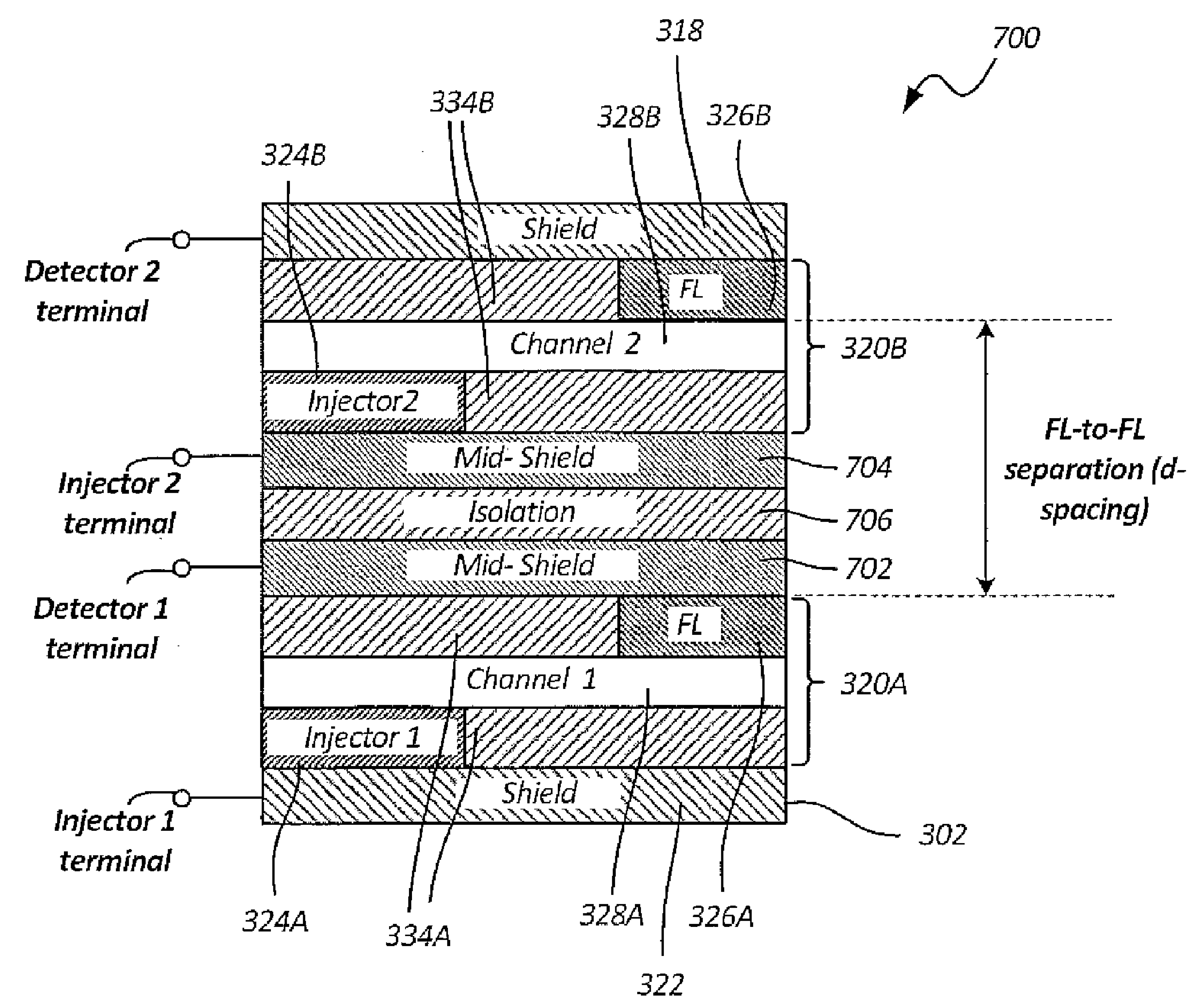

700
318
334B
328B
326B
324B
Shield
FL
Channel 2
Injector2
Mid- Shield
Isolation
Mid- Shield
FL
Channel 1
Injector 1
Shield
Detector 2 terminal
Injector 2 terminal
Detector 1 terminal
Injector 1 terminal
320B
704
706
702
320A
302
FL-to-FL separation (d-spacing)
324A
334A
328A
326A
322

FIG. 7

LATERAL SPIN VALVE READER WITH LARGE-AREA TUNNELING SPIN-INJECTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is based on and claims the benefit of U.S. provisional patent application Ser. No. 62/175,540, filed Jun. 15, 2015, the content of which is hereby incorporated by reference in its entirety.

BACKGROUND

Data storage devices commonly have a recording head that includes a read transducer that reads information from a data storage medium and a write transducer that writes information to a data storage medium.

In magnetic data storage devices such as disc drives, a magnetoresistive (MR) sensor such as a Giant Magnetoresistive (GMR) sensor or a Tunnel Junction Magnetoresistive (TMR) sensor has traditionally been employed as the read transducer to read a magnetic signal from the magnetic media. The MR sensor has an electrical resistance that changes in response to an external magnetic field. This change in electrical resistance can be detected by processing circuitry in order to read magnetic data from the adjacent magnetic media.

The ever increasing need for increased data storage necessitates ever increasing data density in magnetic data storage devices. One way to increase data density is to decrease the size and spacing of magnetic bits recorded on the media. The read sensor is generally sandwiched between a pair of magnetic shields, the spacing between which determines the bit length, also referred to as gap thickness. Sensors such as GMR or TMR sensors are constructed as a stack of layers all formed upon one another sandwiched between the magnetic shields. Accordingly, the ability to reduce the spacing between shields with such a sensor structure is limited.

SUMMARY

The present disclosure relates to a lateral spin valve reader that addresses scaling challenges posed by greater data density requirements and includes one or more features that decrease a total reader resistance and increase an amplitude of a bit detection signal. The lateral spin valve reader includes a channel layer having a first end that is proximate to a bearing surface and a second end that is away from the bearing surface. The lateral spin valve reader also includes a detector structure disposed over an upper surface of a first portion of the channel layer that is proximate to the first end of the channel layer. A spin injection structure disposed below a lower surface of a second portion of the channel layer is proximate to the second end of the channel layer. An area of overlap between the spin injection structure and the second portion of the channel layer is substantially larger than an area of overlap between the detector structure and the first portion of the channel layer.

Other features and benefits that characterize embodiments of the disclosure will be apparent upon reading the following detailed description and review of the associated drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a data storage system.

FIG. **2** is a generalized functional block diagram of a data storage system.

FIG. **3**A is a schematic diagram of a cross-section of one embodiment of a recording head that reads from and writes to a storage medium.

FIGS. **3**B, **3**C and **3**D are schematic diagrams of cross-sections of other embodiments of a recording head that reads from and writes to a storage medium.

FIG. **4**A is a schematic perspective view of a lateral spin valve reader in accordance with one embodiment.

FIG. **4**B is a top view of the lateral spin valve reader of FIG. **4**A.

FIG. **5** is a schematic diagram of a cross-section of a lateral spin valve reader in accordance with one embodiment.

FIGS. **6**A, **6**B and **6**C are schematic diagrams of cross-sections of lateral spin valve readers with different lead terminal configurations.

FIG. **7** is a diagrammatic illustration of a cross-section of a multi-sensor reader in accordance with one embodiment.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Magnetic reader embodiments described below relate to lateral spin valve (LSV) readers that include a spin injector, a detector and a channel layer extending from the spin injector to the detector. The spin injector injects electron spins into the channel layer, which transports the spins to the detector. At the detector, the spins aid in detecting bits stored on a magnetic data storage medium. To decrease a total reader resistance and increase an amplitude of the bit detection signal, different embodiments employ a spin valve reader design that simultaneously increases spin-polarized current and decreases a junction resistance at an injector-channel interface. Prior to providing additional details regarding the different embodiments, a description of an illustrative operating environment is provided below.

FIGS. **1** and **2** together show an illustrative operating environment in which certain specific embodiments disclosed herein may be incorporated. The operating environment shown in FIGS. **1** and **2** is for illustration purposes only. Embodiments of the present disclosure are not limited to any particular operating environment such as the operating environment shown in FIGS. **1** and **2**. Embodiments of the present disclosure are illustratively practiced within any number of different types of operating environments.

FIG. **1** is a perspective view of a hard disc drive **100**. Hard disc drives are a common type of data storage system. While embodiments of this disclosure are described in terms of disc drives, other types of data storage systems should be considered within the scope of the present disclosure. The same reference numerals are used in different figures for same or similar elements.

Disc drive **100** includes a data storage medium (for example, a magnetic disc) **110**. Those skilled in the art will recognize that disc drive **100** can contain a single disc or multiple discs. Medium **110** is mounted on a spindle motor assembly **115** that facilitates rotation of the medium about a central axis. An illustrative direction of rotation is shown by arrow **117**. Each disc surface has an associated recording head **120** that carries a read transducer and a write transducer for communication with the surface of the disc. Each head **120** is supported by a head gimbal assembly **125**. Each head gimbal assembly (HGA) **125** illustratively includes a suspension and a HGA circuit. Each HGA circuit provides electrical pathways between a recording head and associated hard disc drive electrical components including preamplifiers, controllers, printed circuit boards, or other components.

Each suspension mechanically supports an HGA circuit and a recording head **120**, and transfers motion from actuator arm **130** to recording head **120**. Each actuator arm **130** is rotated about a shaft by a voice coil motor assembly **140**. As voice coil motor assembly **140** rotates actuator arm **130**, head **120** moves in an arc between a disc inner diameter **145** and a disc outer diameter **150** and may be positioned over a desired track such as **152** to read and/or write data.

FIG. **2** is a generalized block diagram of illustrative control circuitry for the device shown in FIG. **1**. The control circuitry includes a processor or controller **202** that directs or manages the high level operations of device **100**. An interface circuit **204** facilitates communication between device **100** and a host device **250**. A read/write channel **206** operates in conjunction with a preamplifier/driver circuit (preamp) **208** to write data to and to read data from a data storage medium such as medium **110** in FIG. **1**. Preamp **208** also optionally acts as a power supply to electrical components included in a recording head such as a read transducer, a write transducer, heaters, etc. Preamp **208** is illustratively electrically connected to recording head **120** through a HGA circuit that is connected to preamp **208** and to one or more recording head **120** electrical connection points. A servo circuit **210** provides closed loop positional control for voice coil motor **140** that positions recording head **120**.

FIG. **3**A is a schematic diagram showing a cross-sectional view of portions of a recording head **300** and a data storage medium **350** taken along a plane substantially normal to a plane of a bearing surface (for example, an air bearing surface (ABS)) **302** of recording head **300**. The recording head elements shown in FIG. **3**A are illustratively included in a recording head such as recording head **120** in FIGS. **1** and **2**. Medium **350** is illustratively a data storage medium such as medium **110** in FIG. **1**. Those skilled in the art will recognize that recording heads and recording media commonly include other components. Embodiments of the present disclosure are not limited to any particular recording heads or media. Embodiments of the present disclosure may be practiced in different types of recording heads and media.

Recording head **300** includes a write pole **305**, a magnetization coil **310**, a return pole **315**, a top shield **318**, a read transducer **320**, a bottom shield **322** and a wafer overcoat **336**. Storage medium **350** includes a recording layer **355** and an underlayer **360**. Storage medium **350** rotates in the direction shown by arrow **365**. Arrow **365** is illustratively a direction of rotation such as arrow **117** in FIG. **1**.

In an embodiment, electric current is passed through coil **310** to generate a magnetic field. The magnetic field passes from write pole **305**, through recording layer **355**, into underlayer **360**, and across to return pole **315**. The magnetic field illustratively records a magnetization pattern **370** in recording layer **355**. Read transducer **320** senses or detects magnetization patterns in recording layer **355**, and is used in retrieving information previously recorded to layer **355**.

In the embodiment shown in FIG. **3**A, read transducer **320** is a LSV reader. LSV reader **320** includes a spin injector **324**, a detector **326** and a channel layer **328** that extends from spin injector **324** to detector **326**.

The spin injector **324** may include an electrically conductive, magnetic layer (not separately shown in FIG. **3**A) that has a magnetization that is pinned in a direction (preferably perpendicular to the bearing surface). Pinning of the magnetization of the pinned magnetic layer may be achieved by, for example, exchange coupling with a layer of anti-ferromagnetic material (not separately shown in FIG. **3**A).

The detector **326** may include a magnetic, electrically conductive layer having a magnetization that is free to move in response to a magnetic field, and can therefore be referred to herein as a free layer (FL). Injector **324** and/or detector **326** may be separated from channel layer **328** by a thin electrically insulating barrier layer **338**. A thickness of barrier layer **328** is denoted by reference numeral **340**.

The portion of LSV reader **320** proximate to the bearing surface **302** does not include relatively thick synthetic antiferromagnetic (SAF) and antiferromagnetic (AFM) stacks that are typically present in, for example, current perpendicular-to-plane (CPP) Tunnel Junction Magnetoresistive (TMR) readers. Therefore, a spacing between top shield **318** and bottom shield **322** of LSV reader **320**, which is denoted by s, is substantially less than a shield-to shield spacing in, for example, a CPP TMR reader. It should be noted that, in the interest of simplification, shield-to-shield spacing s in the Z-axis direction in FIG. **3**A is shown as being uniform along a length (in the Y-axis direction) of LSV reader **320**. However, in different embodiments, to accommodate a multi-layered injector **324**, a shield-to-shied spacing away from the bearing surface **302** may be substantially greater than the shield-shield spacing s proximate to the bearing surface **302**.

For allowing a detection current to flow to detector **326**, spin injector **324** is connected to a current source (not shown) via terminal **330**. Detector **326** is connected to a suitable voltage measuring device (not shown) via terminal **332**.

First, the detection current from the current source is made to flow through the spin injector **324** and through the channel layer **328**. This flow of current causes electron spins to accumulate in channel layer **328**, which then transports the spins to the detector **326**.

When the spins are transported to the detector **326**, an electric potential difference, which varies depending upon an external magnetic field, appears between the detector **326** and the channel layer **328**. The voltage measuring device detects electric potential difference appearing between the detector **326** and the channel layer **328**. In this manner, the LSV reader **320** can be applied as an external magnetic field sensor for detecting bits stored on a magnetic data storage medium such as **350**.

In some embodiments, to suppress spin-scattering at surfaces of the channel layer, an exterior cladding (such as **334**) may be disposed around the channel layer **328**. A thickness of cladding layer **334** is denoted by reference numeral **342**. FIG. 3B shows an embodiment of a recording head **375** in which injector **324** is above channel **328** and detector **326** is below channel **328**. In other respects, recording head **375** is substantially similar to recording head **300**. FIGS. **3**C and **3**D show other embodiments of recording heads denoted by reference numerals **380** and **382**, respectively. Other than injector **324** and detector **326** being on a same side of channel layer **328** in recording heads **380** and **382** and bottom shield **322** or top shield **318** being separated into two electrically-isolated portions, recording heads **380** and **382** are substantially similar to recording head **300**.

As noted above, to decrease a total reader resistance and increase an amplitude of the bit detection signal, different embodiments such as **300**, **375**, **380** and **382** employ a spin valve reader design that simultaneously increases spin-polarized current and decreases a junction resistance at an injector-channel interface. One such embodiment is described below in connection with FIGS. **4**A and **4**B.

FIG. **4**A is a schematic perspective view of LSV reader **320** of FIG. **3**A. FIG. **4**B is a top-down view of the LSV reader **320** of FIG. **4**A. As noted earlier, LSV reader **320** includes injector **324**, detector **326** and channel layer **328** that extends from injector **324** to detector **326**. In the interest of simplification, top and bottom shields, etc., are not shown in FIGS. **4**A and **4**B. Tunnel barrier **338** is included between injector **324** and channel layer **328**. To mitigate against resistance that arises due to the inclusion of tunnel barrier **338**, the spin injector may be made larger. Thus, as can be seen in FIG. **4**A, spin injector **324** is a relatively large area spin injector. The relatively large area spin injector **324** is employed to leverage a benefit of the tunnel junction in the injector **324** for suppression of spin-absorption at the injector-channel interface and thereby enhance spin-selectivity and spin-polarized current injected into the LSV channel while simultaneously avoiding elevated resistance from the tunnel junction. Side shields **400** and **402** are included for magnetostatic biasing of the FL of detector **326**. The top-down view of LSV reader **320** in included in FIG. **4**B to show the size of the large-area injector **324** compared to the detector **326**.

As can be seen in FIGS. **4**A and **4**B, channel layer **328** includes a paddle region **404**, a flare region **406**, and a tip region **408**. Paddle region **404** illustratively has a width **410**, and tip region **408** illustratively has a width **412**. Flare region **406** has a first side **414** and a second side **416** that is not parallel to side **414**. Sides **414** and **416** start being spaced apart by width **410** and come closer together until they are spaced apart by width **412** (smaller than **410**) as the sides meet tip region **408**. Or, in other words, flare region **406** includes two sides **414** and **416** that are tapered going from paddle region **404** to tip region **408**. In some embodiments, width **410** may range from tens of nanometers to the micron scale. Also, in such embodiments, width **412** may be tens of nanometers or less. It should be noted that dimensions of widths **410** and **412** and not limited to the examples provided herein and any suitable width dimensions may be used in different embodiments. In the embodiment shown in FIGS. **4**A and **4**B, a geometry of injector **324** and tunnel barrier **338** corresponds to a geometry of the paddle region **404** and flare region **406** of channel layer **328**. However, elements **324**, **328** and **338** may be of any suitable shape and the shapes of these elements are not limited to the shapes shown in FIGS. **4**A and **4**B.

FIG. **5** is a schematic diagram of a cross-section of lateral spin valve reader **320** in accordance with one embodiment. As can be seen in the embodiment of FIG. **5**, injector **324** of sensor **320** includes an anti-ferromagnetic (AFM) layer **500** and a synthetic anti-ferromagnetic (SAF) structure that includes a pinned layer **502**, a thin separation layer **504**, which may comprise a metal such as Ruthenium (Ru) in some embodiments, and a reference layer **506**. In the embodiment shown in FIG. **5**, tunnel barrier **338** is included between injector **324** and channel **328**. In some embodiments, detector **326** may comprise multiple layers. In one embodiment, detector **326** may comprise a CoFeB (cobalt, iron and boron) layer **508** and an additional stack **510**. In some embodiments, the CoFeB layer **508** and the stack **510** may be integrated into a single layer. In some embodiments, no tunnel barrier is employed between detector **326** and channel **328**. In other embodiments, a tunnel barrier **338** is included between detector **326** and channel **328**. Injector **324** and detector **326** are connected by non-magnetic channel **328** but otherwise electrically insulated so no parallel conduction paths are present. In other words, the bottom shield (**322** in FIG. **3**A) does not take part in electrical conduction as in the case of a CPP-style read head. Other aspects of embodiments of LSV reader **320** that are of note are as follows:

1) The SAF/AFM injector **324** or detector **326** may include a conventional magnetic alloy or Heusler alloy for further enhancement of coherent spin injection.

2) Channel **328** may include a non-magnetic metal such as Cu, Mg, Ag, etc.

3) Channel **328** may alternatively be formed of a two-dimensional semiconductor such as graphene or transition-metal dichalcogenide (MoS2, WS2, etc.)

4) Dependent on the type of application, both injector **324** and/or detector **326** may or may not contain a tunnel barrier. The example shown in FIG. **5** is for MgO tunnel barriers. In should be noted that embodiments of LSV reader **320** are not limited to the layers and materials or combinations of materials described above. In different applications, any suitable layers and/or layer materials may be utilized.

In different embodiments, the LSV reader is electrically isolated from any surrounding conductor that may short injector and detector leads. Such surrounding conductors may include magnetic shields and/or secondary spin injectors. It is further noted that two, three, four, or any other number of contacts may be implemented in various embodiments of the LSV reader. The contact configuration utilized depends on a type of detection scheme and application. FIG. **6**A shows an example of an LSV reader such as **320** that has a two-terminal/two-contact (**602** and **604**) configuration. FIG. **6**B shows an example of an LSV reader **320** that has a three-terminal/three-contact (**602**, **604** and **606**) configuration, and FIG. **6**C shows an example a four-terminal/four-contact (**602**, **604**, **606** and **608**) configuration. In some embodiments, it may be more practical from an implementation standpoint that the reader is either 2-terminal as illustrated in FIG. **6**A or 3-terminal as illustrated in FIG. **6**B.

As indicated earlier in connection with the description of FIGS. **3**A and **3**B, an LSV reader such as **320** has a substantially narrow shield-to-shield spacing proximate to a bearing surface such as **302**. The shield-to-shield spacing in the reader such as **320** is determined substantially by the channel and free layers (FL). Therefore, it is a suitable reader design to implement in a multi-sensor configuration where two or more readers are stacked on top of each other within a single recording head such as **300**. An example of a dual-reader configuration is shown in FIG. **7**. The embodiment of reader **700** in FIG. **7** includes a top shield **318** a bottom shield **322** and LSV readers **320**A and **320**B interposed between top shield **318** and bottom shield **322**. Reader **320**A includes a large area injector **324**A, a detector **326**A, a channel **328**A and a cladding **334**A. Similarly, reader **320**B includes a large area injector **324**B, a detector **326**B, a channel **328**B and a cladding **334**B. In the embodiment shown in FIG. **7**, a two-terminal connection configuration is used for each shield. Accordingly, bottom shield **322** and a middle shield **702** are utilized for electrical connection to reader **320**A. Similarly, a middle shield **704** and top shield **318** are utilized for electrical connection to reader **320**B. A suitable isolation layer **706** is interposed between middle shields **702** and **704** to provide the necessary electrical isolation between the shields. It should be noted that FIG. **7** is an illustrative embodiment of a multi-sensor reader and, in other embodiments, more than two sensors may be employed.

In the multi-sensor configuration, a critical parameter is the FL-to-FL spacing, d (in FIG. **7**), and is conventionally set by the additive thicknesses of the stack SAF, mid-shields, and isolation layers. Reducing d enables the multi-sensor reader to be implemented in a higher linear density drive. Substantially drastic d-spacing reduction may be achieved by implementing LSV-based magnetic readers because, as noted above, they eliminate the thicknesses of SAF and AFM stacks at the bearing surface that are typically present in, for example, CPP TMR readers.

Although various uses of the LSV reader with the large-area tunnel-junction injector are disclosed in the application, embodiments are not limited to the particular applications or uses disclosed in the application. It is to be understood that even though numerous characteristics and advantages of various embodiments of the disclosure have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the disclosure, this disclosure is illustrative only, and changes may be made in detail, especially in matters of structure and arrangement of parts within the principles of the present disclosure to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. For example, the particular elements may vary depending on the particular application for the LSV reader with the large-area tunnel-junction injector while maintaining substantially the same functionality without departing from the scope and spirit of the present disclosure. In addition, although the preferred embodiment described herein is directed to particular type of LSV reader with the large-area tunnel-junction injector utilized in a particular data storage system, it will be appreciated by those skilled in the art that the teachings of the present disclosure can be applied to other data storage devices without departing from the scope and spirit of the present disclosure.

What is claimed is:

1. A lateral spin valve reader comprising:

a channel layer having a first end at a bearing surface and a second end that is away from the bearing surface;

a detector structure disposed over an upper surface of a first portion of the channel layer that is proximate to the first end of the channel layer; and

a spin injection structure disposed below a lower surface of a second portion of the channel layer that is proximate to the second end of the channel layer,

wherein an area of overlap between the spin injection structure and the second portion of the channel layer is substantially larger than an area of overlap between the detector structure and the first portion of the channel layer, and

wherein a width of the spin injection structure in a direction parallel to the bearing surface is substantially larger than a width of the detector structure in the directional parallel to the bearing surface, and

wherein the second portion of the channel layer comprises a region that is substantially wider than the first portion of the channel layer in the direction parallel to the bearing surface.

2. The lateral spin valve reader of claim **1** and wherein the width of the spin injection structure in the direction parallel to the bearing surface is tens of nanometers.

3. The lateral spin valve reader of claim **1** and wherein a length of the spin injection structure in a direction perpendicular to the bearing surface is greater that a length of the detector structure in the direction perpendicular to the bearing surface.

4. The lateral spin valve reader of claim **1** and further comprising a tunnel barrier between the spin injection structure and the channel layer.

5. The lateral spin valve reader of claim **3** and wherein no tunnel barrier is included between the detector structure and the channel layer.

6. The lateral spin valve reader of claim **1** and further comprising a tunnel barrier between the detector structure and the channel layer.

7. The lateral spin valve reader of claim **1** and wherein the channel layer comprises a non-magnetic metal.

8. The lateral spin valve reader of claim **1** and wherein the channel layer comprises a semiconductor.

9. The lateral spin valve reader of claim **1** and wherein the spin injection structure comprises a Heusler alloy.

10. The lateral spin valve reader of claim **1** and further comprising a two-terminal configuration.

11. A multi-sensor reader within a single recording head, the multi-sensor reader comprising:

a top shield;

a bottom shield; and

a plurality of lateral spin valve readers interposed between the top shield and the bottom shield, wherein each of the plurality of lateral spin valve readers comprises:

a channel layer having a first end that is proximate to a bearing surface and a second end that is away from the bearing surface;

a detector structure disposed over an upper surface of a first portion of the channel layer that is proximate to the first end of the channel layer; and

a spin injection structure disposed below a lower surface of a second portion of the channel layer that is proximate to the second end of the channel layer,

wherein an area of overlap between the spin injection structure and the second portion of the channel layer is substantially larger than an area of overlap between the detector structure and the first portion of the channel layer;

first and second mid shields between a first one of the plurality of lateral spin valve readers and a second one of the plurality of lateral spin valve readers; and

an isolation layer between the first mid shield and the second mid shield.

12. The multi-sensor reader of claim **11** and wherein, in each of the plurality of lateral spin valve readers, the spin injection structure is substantially larger than the detector structure.

13. The multi-sensor reader of claim **11** and wherein, in each of the plurality of lateral spin valve readers, the second portion of the channel layer comprises a region that is substantially wider than the first portion of the channel layer.

14. The multi-sensor reader of claim **11** and wherein each of the plurality of lateral spin valve readers further comprises a tunnel barrier between the spin injection structure and the channel layer.

15. The multi-sensor reader of claim **14** and wherein, in each of the plurality of lateral spin valve readers, no tunnel barrier is included between the detector structure and the channel layer.

16. The multi-sensor reader of claim **11** and wherein each of the plurality of lateral spin valves readers further comprises a tunnel barrier between the detector structure and the channel layer.

17. The multi-sensor reader of claim **11** and wherein, in each of the plurality of lateral spin valve readers, the channel layer comprises a non-magnetic metal or a semiconductor.

18. The multi-sensor reader of claim **11** and wherein each of the plurality of lateral spin valve readers further comprises a two-terminal configuration, a three-terminal configuration or a four-terminal configuration.

19. A multi-sensor reader within a single recording head, the multi-sensor reader comprising:

a plurality of lateral spin valve readers interposed between a top shield and a bottom shield, wherein each of the plurality of lateral spin valve readers comprises:

a detector structure located proximate to a bearing surface;

a spin injection structure located away from the bearing surface; and

a channel layer extending from the detector structure to the spin injection structure,

wherein an area of overlap between the channel layer and the spin injection structure is substantially larger than an area of overlap between the channel layer and the detector structure,

wherein a first one of the plurality of lateral spin valve readers has a two terminal configuration with only a single detector terminal connected to the top shield and only a single injector terminal connected to a mid shield between the first one of the plurality of lateral spin valve readers and a second one of the plurality of lateral spin valve readers, and no terminal connected to the channel layer.

20. The multi-sensor reader of claim **19** and wherein, in each of the plurality of lateral spin valve readers, the spin injection structure is substantially larger than the detector structure.

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